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# Observation of Pulsed Field-Emission from a Carbon-Nanotube Cathode a HBESL (E-1023)* [on-going work]


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*presented by P. Piot (FNAL & NIU)*


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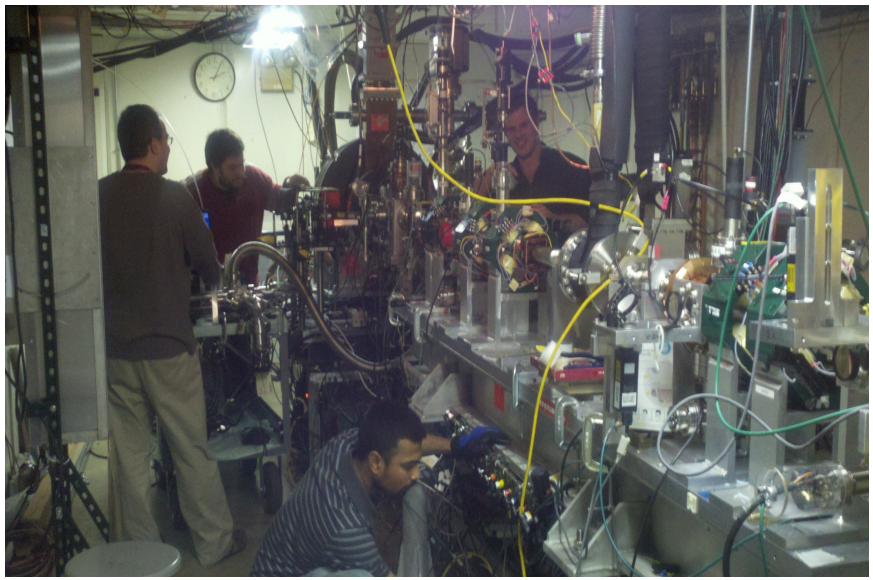
# High-Brightness Electron Source Lab (HBESL)

- **Mission:** R&D on e- sources and lasers
- **Facilities**:
  - ultra-fast laser system
  - 1.3-GHz RF gun+ beamline



- **Recent/on-going experiments:**
  - 2-photon e- emission from $Cs_2Te$,
  - field-emission from diamond arrays,
  - high-current field-emission from CNT
  - VUV light via inverse Compton scatt.
  - tailored e- bunch with laser spatio-temporal shaping.

# Field Emission (FE) & Carbon-nanotube (CNT) Cathodes

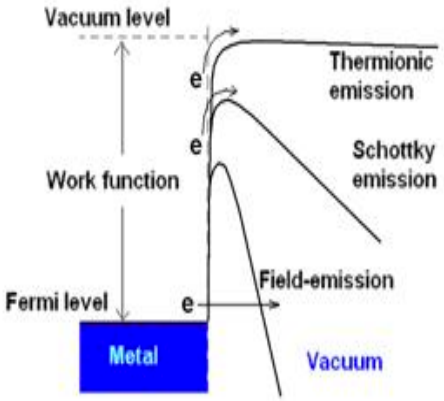
- Current density

material-dependent parameters

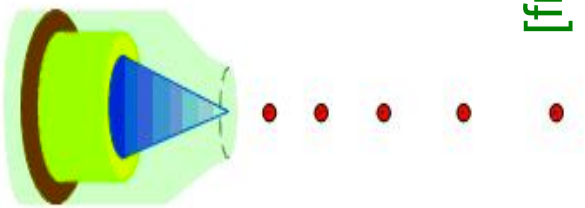
$$j(t) = A(\phi)\beta_e^2 E_z(t)^2 \exp\left(-\frac{B(\phi)}{\beta_e E_z(t)}\right)$$

applied macroscopic field

enhancement factor




[from MiNa, U. BC]



- FE is appealing: no need for an ultra-stable auxiliary laser system
- Single emitter ➔ small transverse emittances
- Array of field emitters ➔ high current w. reduced beam quality, or patterned beams

# Pulsed field emission

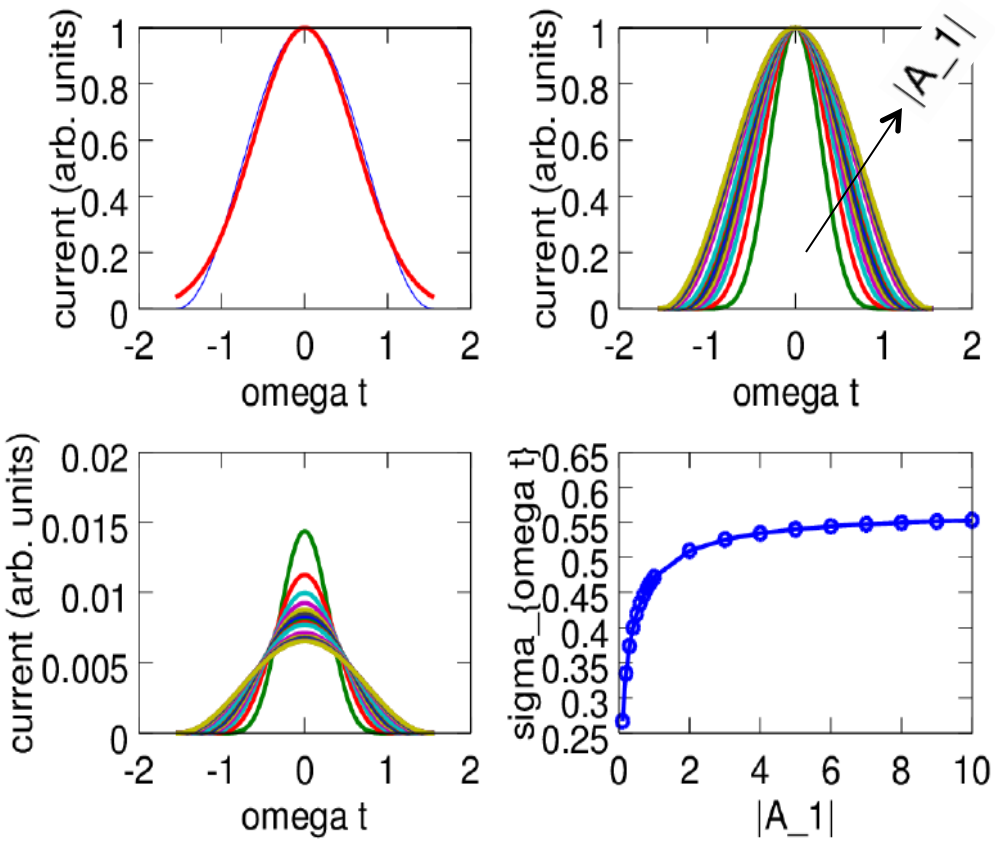
- **Pulsed field emission** can be realized by locating the field emitter in a *t*-dependent field
- single-frequency RF gun not ideal: rms emission time is

$$\sigma_t \simeq \omega^{-1}[\beta_e E_0 / B(\phi)]^{1/2}$$

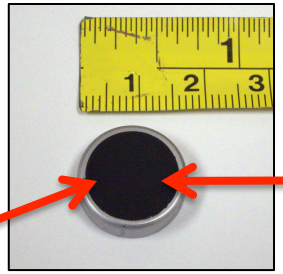
rf frequency

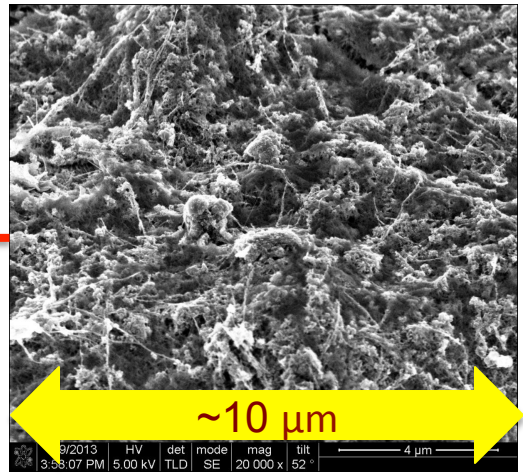
macroscopic field on cathode

- experiments at HBESL uses a 1.3-GHz gun…



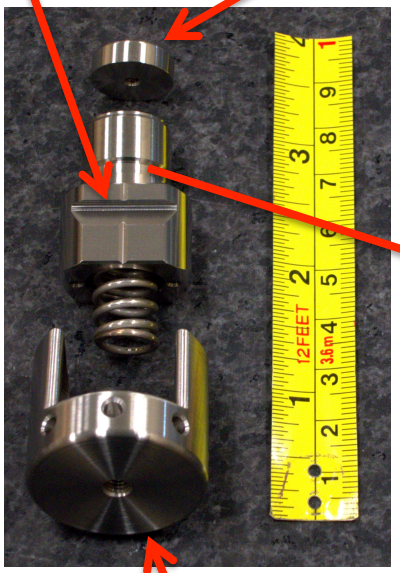
# Experimental setup



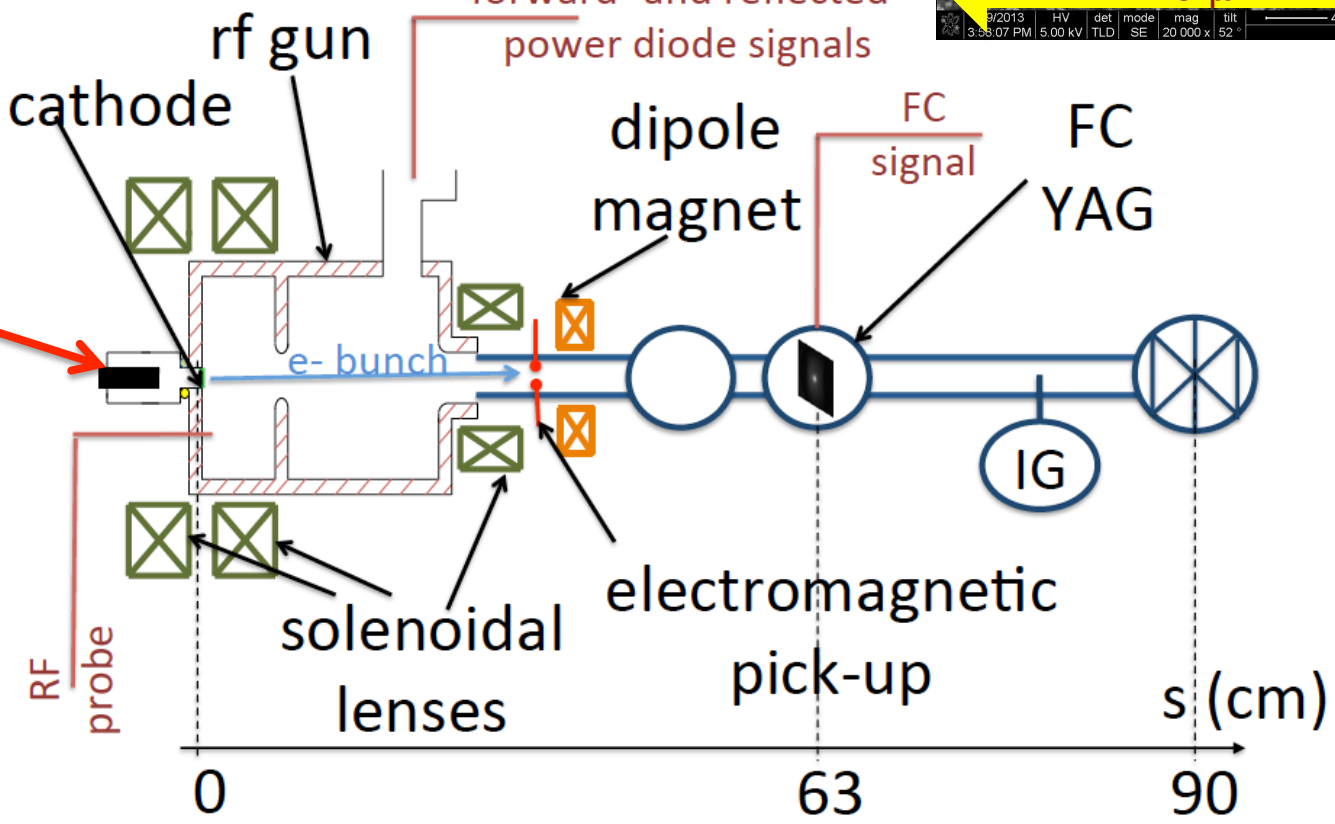



Mo cathode holder

Cathode substrate

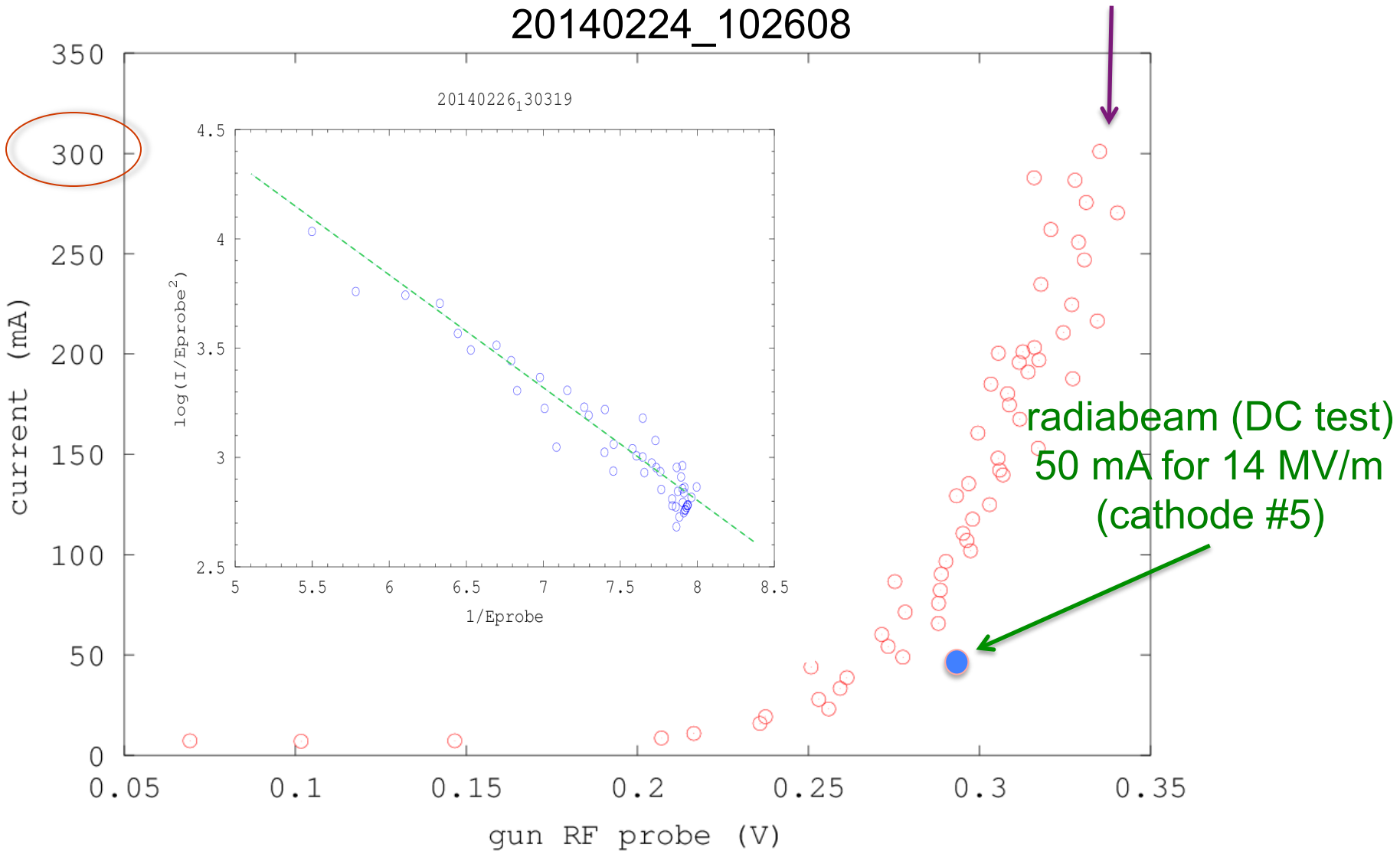


RadiaBeam cathode mount for DC tests

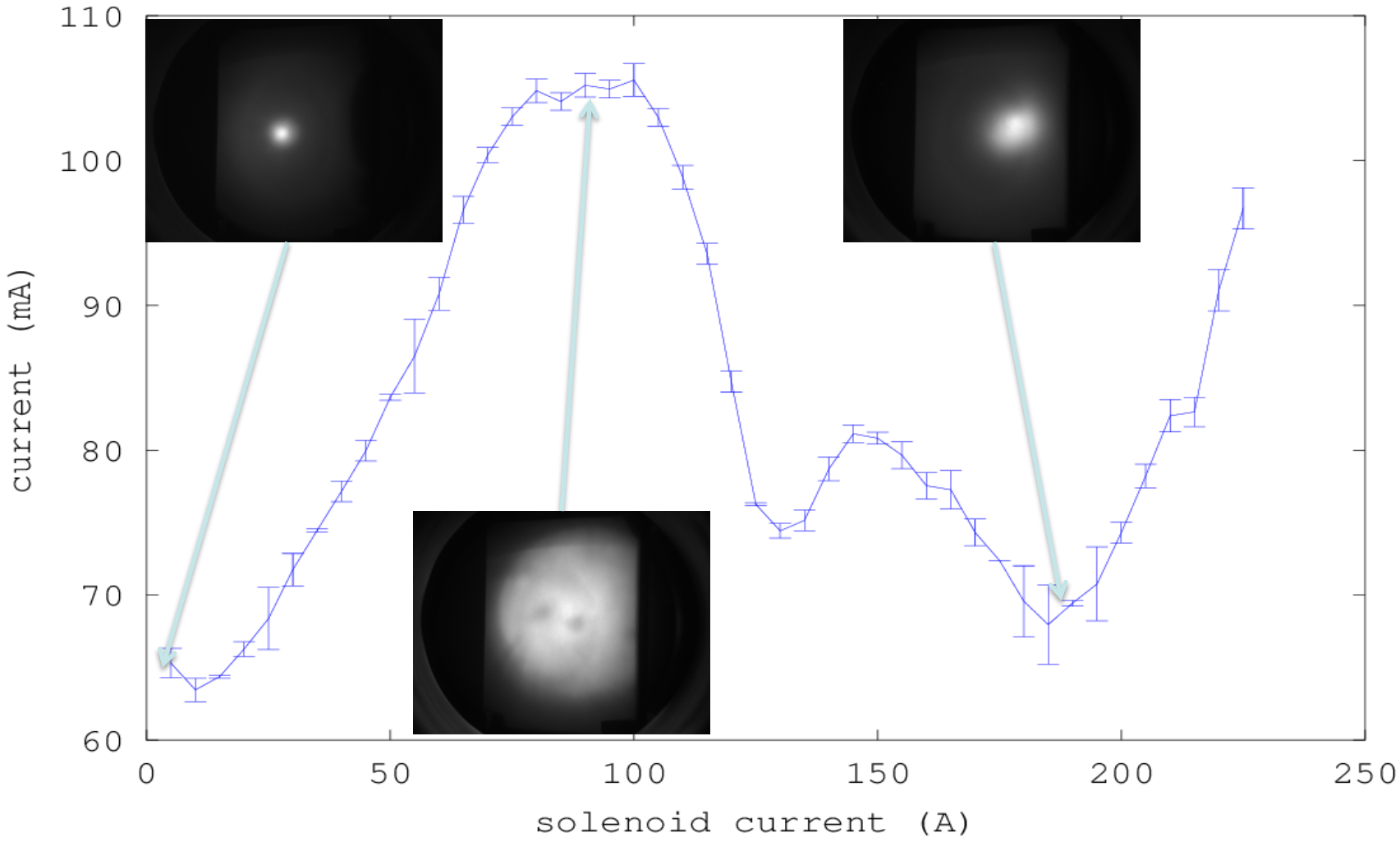



[see also J. Hartzell et al., Proc. NAPAC'13 (2013)]

# Fowler-Nordheim plot

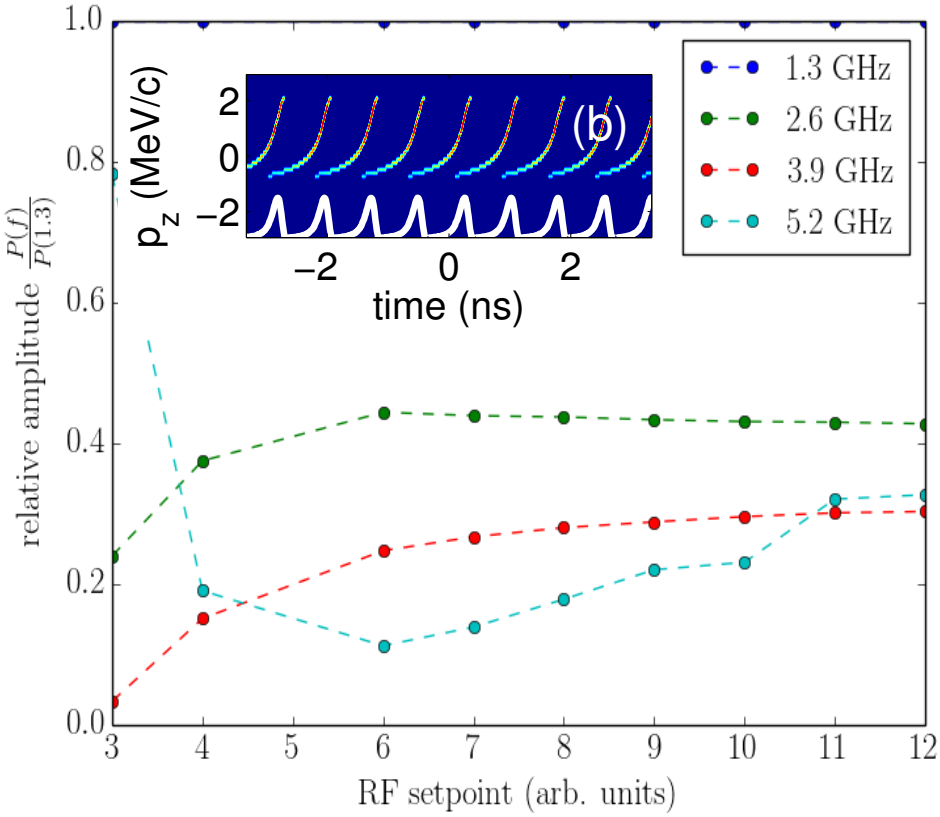


# Beam current + beam density



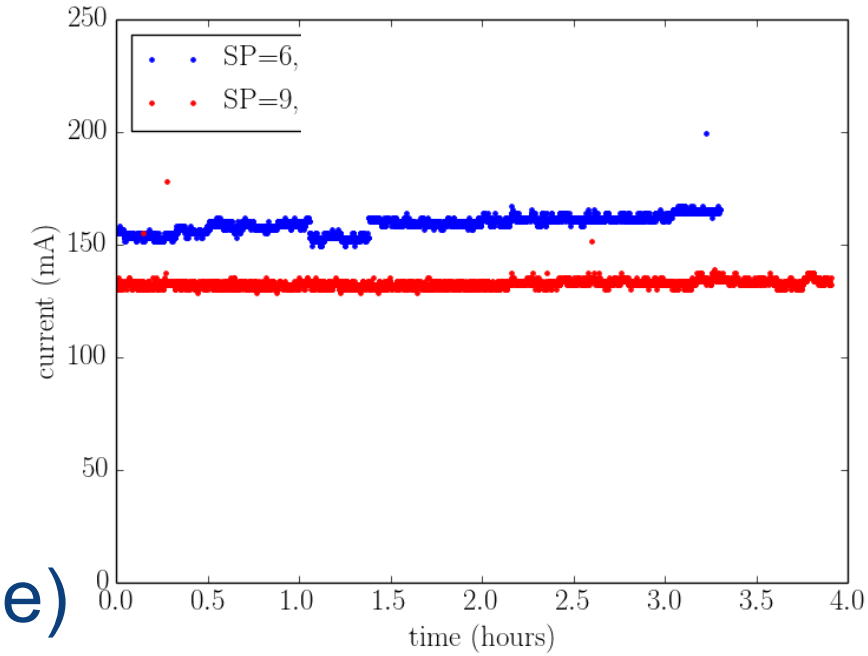
# Observation of pulsed field emission

- electromagnetic pick-up located downstream of the electron source used to detect bunch e.m. fields
- observed 1.3 GHz and harmonic (up to 4$^{th}$ harm).
- inferred bunch length is ~ 50-70 ps
- no significant dependence on applied E field



# Summary/Future

- Preliminary data on field emission from carbon-nanotube cathode are encouraging
- current in excess of 300 mA have been observed
- current stability was measured to be <5% over ~4 hours
- Smaller-area cathode being prepared at CNSI
- Next round of tests (June) will focus on beam emittance measurements



# Credits

- At Fermilab the following people crucially contributed to the success of this experiment:
  - P. Prieto and H. Pfeffer (fixed our pulse transformer),
  - J. Reid, and T. Kubicki (RF support)
  - N. Eddy (fast scope)
- Support from AD/APC
  - E. Harms, S. Nagaitsev, and V. Shiltsev.
- NIU Grad. students: F. Lemery, B. Blomberg (cathode installation, RF measurements)